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RESEARCH ARTICLE

Transcatheter edge-to-edge repair in severe mitral regurgitation following acute myocardial infarction – aetiology-based analysis

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Aims

To evaluate the association between transcatheter edge-to-edge repair (TEER) and outcomes in patients with significant mitral regurgitation (MR) following acute myocardial infarction (MI), focusing on the aetiology of acute post-MI MR in high-risk surgical patients.

Methods and results

The International Registry of MitraClip in Acute Mitral Regurgitation following Acute Myocardial Infarction (IREMMI) includes 187 patients with severe MR post-MI managed with TEER. Of these, 176 were included in the analysis, 23 (13%) patients had acute papillary muscle rupture (PMR) and 153 (87%) acute secondary MR. The mean age was 70 ± 10 years and 41% were female. PMR patients had fewer cardiovascular risk factors: hypertension (52% vs. 73%, $p = 0.04$), diabetes (26% vs. 48%, $p < 0.01$) but a higher left ventricular ejection fraction

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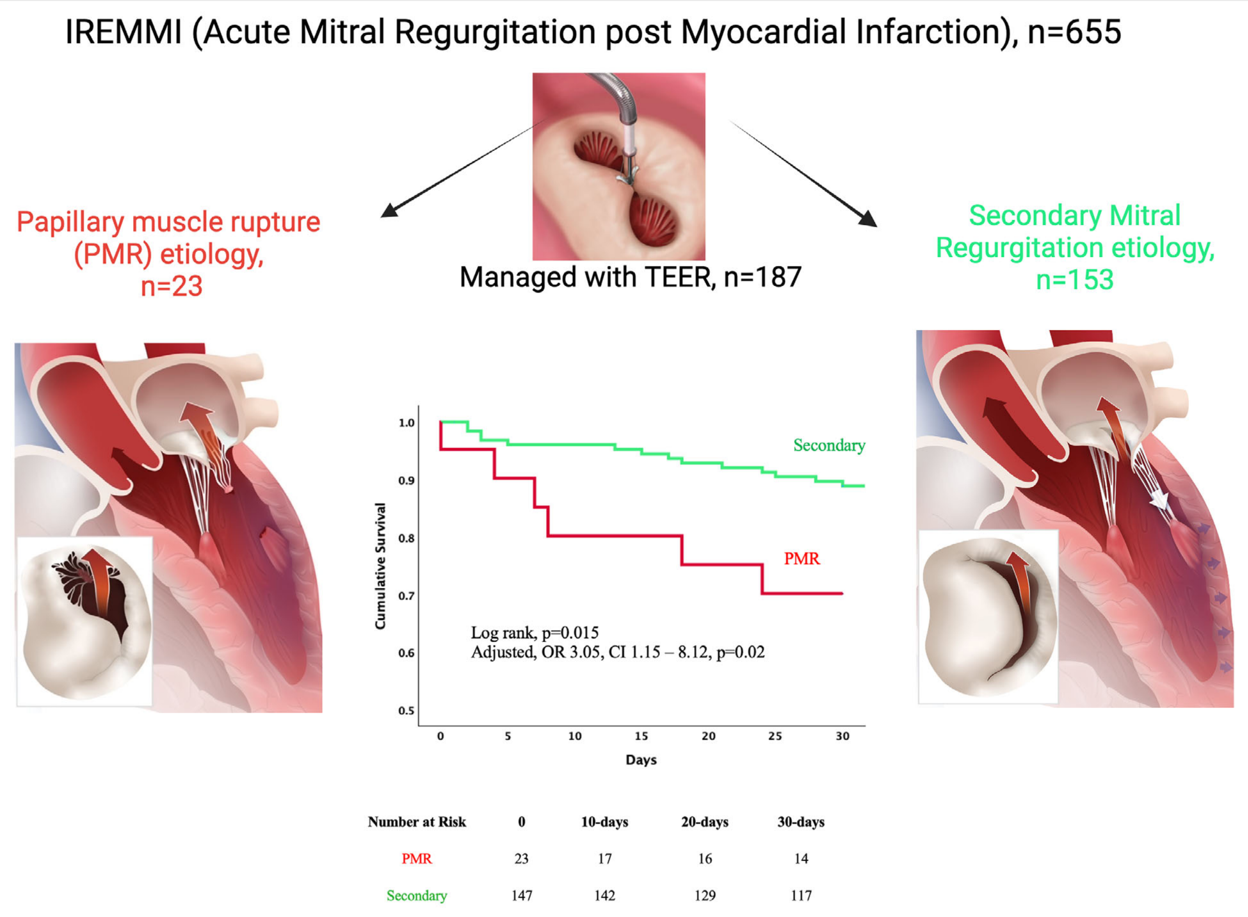
(45± 15% vs.35± 10%, $p<0.01$) compared secondary MR patients. PMR patients were more likely to present in cardiogenic shock (91% vs. 51%, $p=0.001$), require mechanical circulatory support (74% vs. 34%, $p=0.01$), and had a higher EuroSCORE II (23± 13% vs. 13± 11%, $p=0.011$). The median time from MI to TEER was shorter in PMR (6 days) versus secondary MR (20 days) ($p<0.01$). Procedural success was similar (87% vs. 92%, $p=0.49$) with comparable MR grade reduction. However, PMR patients had significantly higher in-hospital mortality rates (adjusted odds ratio [OR] 3.05, 95% confidence interval [CI] 1.15–8.12, $p=0.02$), 30-day mortality rates (unadjusted OR 3.99, 95% CI 1.42–11.26, $p=0.01$) and a higher rate of conversion to surgical mitral valve replacement (22% vs. 3%, $p<0.01$) (unadjusted OR 8.17, 95% CI 2.15–30.96, $p<0.001$). Aetiology of MR, cardiogenic shock, and procedure timing significantly impacted in-hospital mortality. After adjusting for EuroSCORE II and cardiogenic shock, MR aetiology remained the strongest predictor (adjusted OR 6.71; 95% CI 2.06–21.86, $p<0.01$).

Conclusion Transcatheter edge-to-edge repair may be considered a salvage or bridge procedure in decompensated post-MI MR patients of both aetiologies; however, patients with PMR have a higher risk of mortality and conversion to surgery.

Graphical Abstract



The International Registry of MitraClip in Acute Mitral Regurgitation following Acute Myocardial Infarction (IREMMI). CI, confidence interval; OR, odds ratio; TEER, transcatheter edge-to-edge repair.

Keywords Cardiogenic shock • Mitral regurgitation • Myocardial infarction • Papillary muscle rupture • Transcatheter edge-to-edge repair

Introduction

Acute mitral regurgitation (MR) in the context of myocardial infarction (MI) is often associated with haemodynamic instability and has been linked to a poor prognosis.[1–3] It can be caused by primary MR due to papillary muscle rupture (PMR) or by the rapid remodelling of the infarcted left ventricle, which leads to apical tethering of the leaflets, resulting in secondary MR.[4] The rapid onset of regurgitant volume in a non-compliant left atrium leads to a swift increase in left atrial pressure, elevated pulmonary pressures, pulmonary congestion, and forward left ventricular (LV) failure. When acute MR is caused by PMR, outcomes are often fatal due to rapid haemodynamic deterioration.[5] The current management of this condition involves haemodynamic stabilization through medical therapy or mechanical circulatory support, and urgent surgical mitral valve repair or replacement, although the latter is associated with high mortality rates.[6,7] Mitral transcatheter edge-to-edge repair (TEER) is an essential tool for treating unstable patients with severe MR. Emerging data highlight its effectiveness in acutely decompensated patients, including those in cardiogenic shock (CS).[8,9] The International Registry of MitraClip in Acute Mitral Regurgitation following Acute Myocardial Infarction (IREMMI) previously highlighted the superiority of intervention over conservative management in post-MI functional MR and suggested TEER as a viable treatment option, potentially offering advantages over surgery.[10–13] Additionally, a recent study by IREMMI highlighted the potential benefits of TEER in patients with PMR. This study aims to compare the outcomes of PMR and secondary MR post-MI managed with TEER.

Methods

IREMMI registry and study population

The IREMMI evaluates the outcomes and safety of patients who underwent TEER in an acute setting after MI. We contacted all participating centres to review information on patients with post-MI symptomatic MR. Our current study cohort included patients with at least symptomatic grade 3 (moderate-to-severe) MR within 90 days of acute MI (both ST-elevation and non-ST-elevation) between December 2009 and September 2022, across 30 centres in North America, Europe, and the Middle East. This analysis included patients treated with TEER in the acute setting due to PMR (including complete PMR, partial muscle rupture, and chordal rupture) and secondary MR. The study flow chart is detailed in *Figure 1*.

Patients had symptomatic heart failure (HF) despite receiving medical treatment and support. They were evaluated by a multidisciplinary team consisting of a cardiothoracic surgeon, an interventional cardiologist, an imaging specialist, and a non-interventional cardiologist. All patients were treated following contemporary clinical guidelines. Medical care in the intensive care unit, including oral medications, intravenous diuretics, vasoactive agents, mechanical ventilation, and mechanical support devices, was managed by local providers and a multidisciplinary team based on clinical assessment. Since all patients were considered at high surgical risk, salvage TEER procedures were performed to facilitate stabilization and recovery. We evaluated the immediate, 30-day and 1-year outcomes in these patients. The study was conducted following the Declaration of Helsinki ethical principles and was approved by all individual local ethics committees.

Echocardiographic evaluation

The severity of MR, LV ejection fraction (LVEF), systolic pulmonary artery pressure (sPAP), and mitral valve gradient were measured and graded according to the American Society of Echocardiography guidelines.[14,15] The severity of MR was assessed using an integrated multiparametric visual evaluation tool in line with standard clinical practice (incorporating two-dimensional, spectral, and colour Doppler images), using an ordinal scale (grading 0 no MR, 1+ mild MR, 2+ moderate MR, 3+ moderate to severe MR, 4+ severe MR). Complete, chordal papillary or chordal rupture is defined as PMR (primary MR) aetiology. A transoesophageal or tranthoracic echocardiogram was suggested for all patients before the procedure. MR grade, mitral valve area, mitral valve gradient, calcium at the grasping area, and coaptation features were assessed to evaluate TEER feasibility.

Transcatheter edge-to-edge repair

The TEER procedure was performed under general anaesthesia, with fluoroscopy and transoesophageal echocardiography routinely used for guidance. Procedural success was defined as successful grasping of the anterior and posterior leaflets, along with a final MR grade ≤2 at the end of the procedure. Left atrial V-wave and left atrial pressures were measured and recorded immediately before and after TEER. The procedures were completed using the MitraClip device (Abbott Vascular, Menlo Park, CA, USA).

Outcomes

The outcomes of interest included procedural success, safety, in-hospital mortality, 30-day mortality, 1-year mortality, clinical outcomes, and haemodynamics. Acute procedural success was defined as the successful implantation of one or more implants with a reduction of MR and haemodynamic improvement. Safety outcomes encompassed procedural and periprocedural complications such as implant detachment, cerebrovascular events, MI, bleeding requiring transfusion, cardiac tamponade, and urgent cardiovascular surgery. Clinical outcomes included in-hospital (primary outcome) and 30-day mortality, intensive care unit length of stay, and New York Heart Association (NYHA) class at follow-up. Haemodynamic parameters such as left atrial pressure and left atrial V-wave were measured during the procedure (secondary outcomes). In cases where right heart catheterization was used, pulmonary capillary wedge pressure (PCWP) was measured simultaneously. After discharge, patients were followed up by individual centres during outpatient clinic visits, where clinical evaluations and echocardiography were performed. Although hospital data and 30-day follow-up were available for all patients, 13% of participants in the secondary aetiology group were lost to follow-up due to inability to establish contact.

Statistical analysis

Results are reported according to variable properties. Continuous variables (LVEF, PCWP, V-wave, pulmonary artery pressure) are presented based on their distribution: mean ± standard deviation for normally distributed variables (differences between groups were tested using Student's *t*-test) and median (interquartile range [IQR]) for non-normally distributed variables (differences between groups were tested using the Mann–Whitney U test). Categorical variables (MR grade) are reported as numbers (%), and differences between

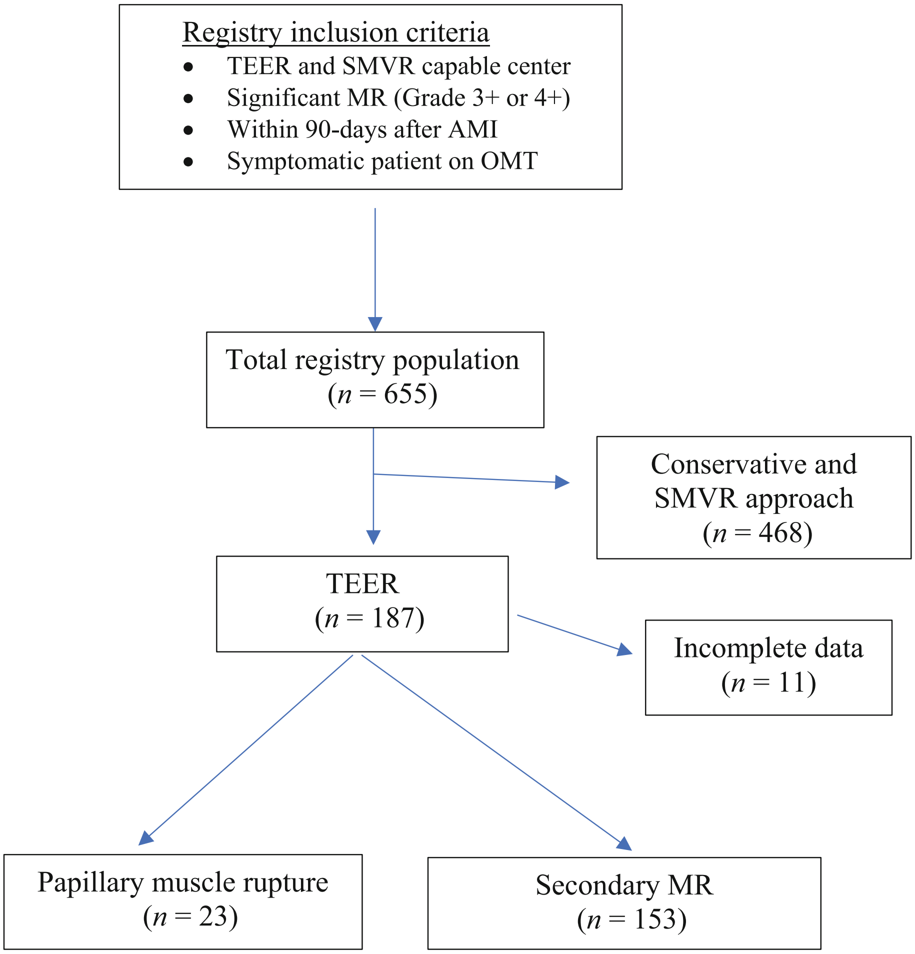


Figure 1 Study flow-chart illustrating patient inclusion in the registry, the division into treatment approaches, and the aetiology of mitral regurgitation (MR). AMI, acute myocardial infarction; OMT, optimal medical therapy; TEER, transcatheter edge-to-edge repair; SMVR, surgical mitral valve repair or replacement.

groups were tested using the Chi-square test. Kaplan–Meier estimates were used to generate survival curves, which were compared using the log-rank test. All clinical events were analysed based on the time to the first event for Kaplan–Meier analysis. We conducted univariate and multivariable logistic regression analysis using the backward elimination method (with likelihood ratio as the removal criterion) for in-hospital mortality and Cox regression analysis for 30-day and 1-year mortality. These analyses included a range of clinically significant co-factors: age, sex, comorbidities, Killip class, LVEF, and the use of a mechanical support device. Differences were considered statistically significant at $p < 0.05$. Analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) Statistics 29.0 (IBM Corp., Armonk, NY, USA).

Results

Patient characteristics

The IREMMI study included a total of 655 patients, of whom 187 (29%) underwent percutaneous treatment with TEER. Eleven cases were excluded from the analysis due to incomplete data. The final group consisted of 176 patients who had encountered severe MR following an acute MI, as previously described (*Figure 1*). Out of 176 cases, 23 (13%) were attributed to PMR, while 153 (87%) were due to secondary aetiology. *Table 1* provides a summary of the baseline characteristics of the patients. Mean age was 70 ± 10 years, with no significant difference between PMR and secondary aetiology (68 ± 13 vs. 71 ± 11, $p = 0.315$). There was a slight predominance of males in both groups (56% vs. 58%, $p = 0.881$). Patients with significant MR due to PMR had fewer comorbidities at baseline comparing those with secondary aetiology: hypertension (52% vs. 73%, $p = 0.039$), diabetes mellitus (26% vs. 48%, $p = 0.007$) and dyslipidaemia (35% vs. 66%, $p = 0.003$). Both groups had a high rate of multivessel coronary artery disease (67% vs. 83%, $p = 0.10$) and prior MI (69% vs. 53%, $p = 0.145$). Coronary artery bypass graft was less common in patients with PMR (4% vs. 27%, $p = 0.02$). Most of the patients presented with ST-elevation MI without significant difference between groups (57% vs. 69%, $p = 0.145$). Percutaneous coronary intervention (PCI) was performed at rates of 83% and

Table 1 Baseline characteristics

Variable	PMR ($n = 23$)	Secondary MR($n = 153$)	p-value
Age, years	67.6 ± 13.2	70.6 ± 10.1	0.315
Female sex	10 (43.5)	64 (41.8)	0.881
BMI, kg/m^2	26 ± 6.2	26.3 ± 4.6	0.608
Hypertension	12 (52)	112 (73)	0.039
Diabetes	6 (26)	73 (48)	0.007
Dyslipidaemia	8 (35)	101 (66)	0.003
COPD	2 (9)	28 (19)	0.376
Prior stroke	3 (13)	19 (13)	0.99
CKD grade ≥ 2	6 (26)	50 (33)	0.661
Multivessel coronary disease	14 (67)	119 (83)	0.10
Prior MI	16 (69)	81 (53)	0.145
Prior CABG	1 (4.3)	40 (27)	0.02
EuroSCORE II, %	23 ± 13	13 ± 11	0.011
STEMI presentation	12 (57)	98 (69)	0.145
Involved wall-anterior	7 (30)	48 (31)	0.92
PCI	19 (83)	145 (95)	0.304
PCI in first 24 h	18 (78)	101 (66)	0.27
Killip class	3.8 ± 0.5	3.17 ± 0.9	0.01
sPAP, mmHg	47± 20	52 ± 18	0.234
LVEF, %	45 ± 15	35 ± 10	0.002
Cardiogenic shock	19 (91)	73 (51)	0.001
Mechanical ventilation	18 (86)	60 (41)	<0.001
Vasoactive medication	19 (91)	68 (47)	<0.001
IABP	15 (65)	46 (30)	0.002
Impella	6 (26)	4 (3)	<0.001
VA-ECMO	4 (17)	6 (4)	0.025
Any MCS	17 (74)	51 (34)	0.01

Values are given as mean ± standard deviation, or n (%).
BMI, body mass index; CABG, coronary artery bypass grafting; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; IABP, intra-aortic balloon pump; LVEF, left ventricular ejection fraction; MCS, mechanical circulatory support; MI, myocardial infarction; MR, mitral regurgitation; PCI, percutaneous coronary intervention; PMR, papillary muscle rupture; sPAP, systolic pulmonary artery pressure; STEMI, ST-elevation myocardial infarction; VA-ECMO, veno-arterial extracorporeal membrane oxygenation.

95%, which was not statistically significant ($p = 0.304$) nor PCI in the first 24 h (78% vs. 66%, $p = 0.27$). During hospitalization, all patients were treated in intensive care units. Patients with PMR had a significantly higher incidence of CS (91% vs. 51%, $p = 0.001$), greater utilization of mechanical circulatory support (74% vs. 34%, $p = 0.01$), predominantly intra-aortic balloon pump (IABP) (61% vs. 30%, $p < 0.01$), and an elevated surgical risk as measured by EuroSCORE (23 ± 13% vs. 13 ± 11%, $p = 0.011$).

Echocardiography confirmed that all patients had significant MR despite coronary revascularization and guideline-directed medical therapy. Patients with PMR exhibited less severe LV dysfunction, as indicated by LVEF (45 ± 15% vs. 35 ± 10%, $p = 0.002$). The mechanism of PMR was complete muscle rupture in 9 patients (39%), partial rupture in 9 patients (39%), and chordal rupture in 5 patients (22%).

Procedural characteristics and haemodynamic outcomes

Table 2 summarizes the procedural characteristics and in-hospital outcomes. The TEER procedure was performed at an earlier stage in the PMR group (time from MI presentation to procedure 6 days, IQR 3.5–12) compared to the secondary MR group (20 days, IQR 12–37) ($p < 0.01$). In both aetiologies, the majority of patients required two implants during the procedure (44% in PMR and 53% in secondary MR), with no significant difference in implant usage between groups ($p = 0.21$). In one PMR patient, four TEER devices were implanted. The total average procedure time was less than 2 h, with a median of 117 min (IQR 60–150) for PMR and 92 min (IQR 60–128) for secondary MR ($p = 0.28$). Procedural success was high in both groups, with rates of 87% and 92% ($p = 0.49$). MR grade was significantly reduced after the procedure in both groups ($p < 0.01$). Reduction to 0 or 1+ was achieved in 52% of PMR patients and 57% of patients with secondary aetiology, to 2+ in 35% of patients in both groups; persistence of 3+ or 4+ MR occurred in 13% and 8% of patients, respectively (*Figure* 2A). MR reduction was associated with improved haemodynamics, as evidenced by a reduction in left atrial V-wave from 50 ± 8 mmHg to 25 ± 11 mmHg in the PMR group and from 35 ± 16 mmHg to 20 ± 8 mmHg in the secondary MR group after the procedure ($p < 0.001$) (*Figure* 2B). The mitral valve gradient at discharge was similar between groups, measuring 4.3 ± 1.5 mmHg and 4.1 ± 1.9 mmHg ($p = 0.35$). No differences were observed in LVEF at presentation and discharge

Table 2 Procedural characteristics and outcomes

Variable	PMR ($n = 23$)	Secondary MR($n = 153$)	p-value
MI to procedure, days	6 (3.5–12)	20 (12–37)	<0.01
Procedure time, min	117 (60–150)	92 (60–128)	0.28
TEER device implanted			0.21
1	40%	35%	
2	44%	53%	
3	12%	6%	
4	4%		
Procedure success	20 (87)	140 (92)	0.49
Major complications	2 (9)	12 (8)	0.36
Hospital stay, days	18 (12–29)	16 (8–31)	0.68
ICU stay, days	12 (7–18)	8 (2–20)	0.17
In-hospital mortality	7 (30)	10 (7)	<0.01
30-day mortality	7 (30)	15 (10)	0.012
1-year mortality	8 (35)	28 (18)	0.18
Conversion to MVR	5 (22)	5 (3)	<0.01
Time to MVR conversion, days	195 (95–270)	196 (15–365)	NS

Values are given as n (%), or median (interquartile range).
ICU, intensive care unit; MI, myocardial infarction; MR, mitral regurgitation; MVR, mitral valve repair or replacement; PMR, papillary muscle rupture; TEER, transcatheter edge-to-edge repair.

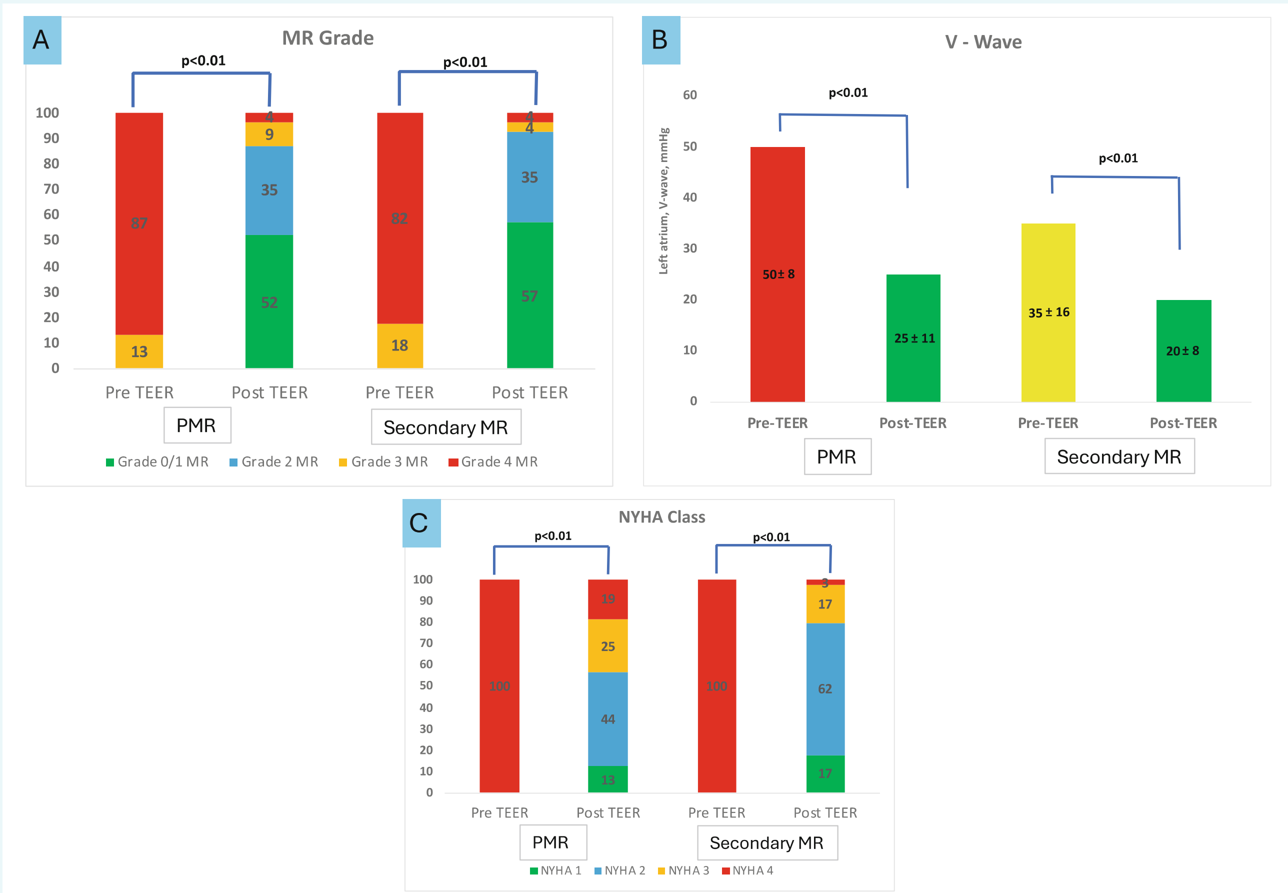


Figure 2 Haemodynamic and functional outcomes. (*A*) Echocardiographic assessment of mitral regurgitation (MR) grade before and after transcatheter edge-to-edge repair (TEER) showed a significant reduction in MR grade across both aetiologies. (*B*) Haemodynamic assessment of left atrial (or wedge) pressure V-wave before and after TEER showed a significant reduction in V-wave in both aetiologies. (*C*) Clinical evaluation using the New York Heart Association (NYHA) functional class before TEER and at discharge showed a significant improvement in NYHA class across both aetiologies. PMR, papillary muscle rupture.

in both the PMR group (45 ± 15% vs. 43 ± 14%, $p = 0.37$) and the secondary group (35 ± 10% vs. 35 ± 9%, $p = 0.87$).

Mortality and follow-up

In-hospital mortality was significantly higher in the PMR group compared to the secondary aetiology group (30% vs. 7%, $p < 0.01$) (*Table 2*). The difference in mortality between the groups remained consistent at the 30-day follow-up (30% vs. 10%, $p = 0.012$). Non-adjusted Kaplan–Meier curves are shown in *Figure 3*. PMR was associated with higher mortality risk within 30 days (log-rank, $p = 0.015$) (unadjusted odds ratio [OR] 3.99, 95% confidence interval [CI] 1.42–11.26, $p = 0.01$). In the univariate model for in-hospital mortality, the aetiology of MR was the most significant factor influencing the primary outcome, with an OR of 8.24 (95% CI 2.92–23.27, $p < 0.01$). Early treatment with TEER was associated with reduced mortality (OR 0.96, 95% CI 0.93–0.99, $p = 0.04$); however, this association was not maintained after multivariable adjustment. In the multivariable model, even after adjusting for EuroSCORE II and CS, the aetiology of MR remained the most significant factor, with an adjusted OR of 6.71 (95% CI 2.06–21.86, $p < 0.01$), as shown in *Table 3*. This was consistent in a model predicting 30-day mortality, where MR aetiology was linked to a higher mortality risk (OR 3.08, 95% CI 1.18–8.01, $p = 0.02$), alongside age and EuroSCORE II. The aetiology of MR remained the most significant factor, with an adjusted OR of 3.05 (95% CI 1.15–8.12, $p = 0.02$), as presented in online supplementary *Table Appendix S1*.

Given the complexity of these patients, procedural complication rates remained relatively low, at 9% and 8%, ($p = 0.36$). Both aetiologies of MR undergoing TEER had a prolonged length of hospital stay (18 [IQR 12–29] days and 16 [IQR 8–31] days, respectively, $p = 0.68$). Significant clinical improvement was observed at discharge. Among survivors, 57% of patients in the PMR group and 79% in the secondary MR group were in NYHA class I or II (*Figure 2C*).

Five patients (22%) in the PMR group eventually underwent surgical mitral valve repair or replacement within a median of 195 days

(IQR 95–270), all of whom survived at 1 year. In comparison, five patients (3%) in the secondary MR group underwent surgical mitral valve repair or replacement (unadjusted OR 8.17, 95% CI 2.15–30.96, $p < 0.001$), within a median of 196 days (IQR 15–365) ($p < 0.01$). Of these, two patients did not survive, and one patient underwent a heart transplant.

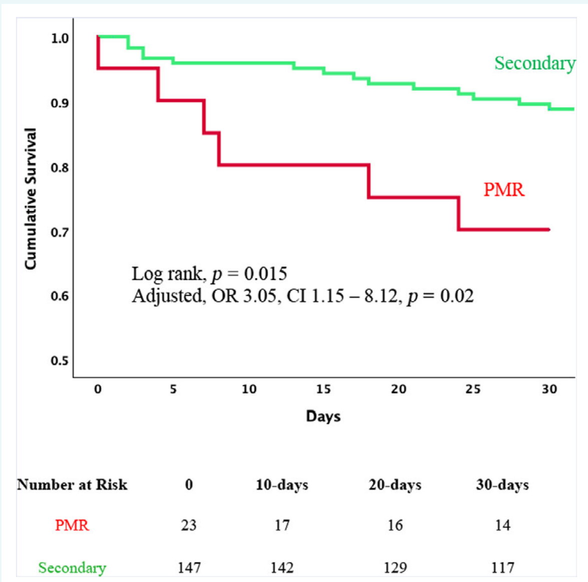


Figure 3 Kaplan–Meier curve of 30-day mortality showing that papillary muscle rupture (PMR) aetiology was associated with a higher mortality rate than secondary mitral regurgitation. CI, confidence interval; OR, odds ratio.

Discussion

Transcatheter edge-to-edge repair has become an attractive treatment option for patients with acute severe MR and decompensated HF. The less invasive nature of TEER, with its high safety profile and immediate haemodynamic improvement, provides potential benefits for high-risk populations such as those with post-MI MR.[8,16,17] The current study compared the clinical features and outcomes of in post-MI patients with PMR with those with secondary MR in a large multicentre registry. The major findings are that most cases of post-MI MR treated with TEER patients are of secondary aetiology (*Graphical Abstract*). The clinical presentation is more severe in patients with PMR, with over 90% of these patients presenting in CS. Procedural success in the PMR group was high at 87%, which is comparable to real-world data for degenerative MR (89%).[18] Procedural success in the secondary group (92%) was slightly lower than randomized studies for functional MR (about 95%).[19] Although the immediate procedural success was similar between groups, outcomes for PMR patients were significantly worse, with an in-hospital mortality rate of 30%. Additionally, nearly 25% of these patients eventually required surgical intervention. The median time from the TEER procedure to surgery was 195 days, providing a significant interval from the acute event and potentially allowing the surgery to be performed in a more controlled, elective setting.

Post-MI MR includes PMR or secondary MR due to rapid LV remodelling leading to stretching and tethering of the mitral leaflets.[20] PMR, most frequently seen after inferior or lateral MI in patients with no history of prior coronary artery disease, is more common with ST-elevation MI than non-ST-elevation MI.[21] Secondary MR occurs more frequently with inferior infarctions due to geometric distortion in the region of the papillary muscle.

Table 3 Univariate and multivariate model of in-hospital mortality

Variable	Univariate		Multivariate	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age	1.04 (0.99–1.09)	0.15		
Female sex	2.19 (0.85–5.67)	0.11		
Hypertension	0.97 (0.35–2.69)	0.96		
Diabetes	1.13 (0.44–2.86)	0.80		
Body mass index	0.94 (0.82–1.06)	0.30		
Chronic kidney disease	1.12 (0.75–1.66)	0.59		
Aetiology: PMR vs. secondary MR	8.24 (2.92–23.27)	<0.001	6.71 (2.06–21.86)	0.002
LVEF	0.97 (0.93–1.02)	0.22		
EuroSCORE II	1.05 (1.02–1.07)	<0.001	1.04 (1.01–1.07)	0.005
Killip class	1.90 (0.96–3.79)	0.07		
Cardiogenic shock	3.68 (1.18–11.55)	0.03	1.33 (0.36–4.95)	0.67
Time to PCI	0.66 (0.33–1.34)	0.25		
Time to TEER	0.96 (0.93–0.99)	0.04	0.99 (0.96–1.02)[a]	
MCS	1.28 (0.48–3.14)	0.63		
Vasoactive medications	1.81 (0.68–4.79)	0.23		
Mechanical ventilation	2.99 (1.09–8.21)	0.034	1.78 (0.56–5.71)[a]	0.33

CI, confidence interval; LVEF, left ventricular ejection fraction; MCS, mechanical circulatory support; MR, mitral regurgitation; OR, odds ratio; PCI, percutaneous coronary intervention; PMR, papillary muscle rupture; TEER, transcatheter edge-to-edge repair.
[a]When exchanged for cardiogenic shock in multivariate model.

However, secondary MR complicating anterior ST-elevation MI is associated with poorer short- and long-term outcomes than inferior wall infarcts.[22]

Regardless of the aetiology, both PMR and secondary post-MI MR might lead to acute and severe HF. The combination of ischaemic LV damage and acute MR is part of a vicious cycle that promotes further clinical deterioration. The medical treatment of acute MR typically involves intravenous diuretics, vasodilators, inotropic support, and sometimes mechanical support to stabilize the patients. The intra-aortic balloon pump is the first-line option for mechanical support. Trans-aortic microaxial pumps, such as the Impella CP or Impella 5.5 (Abiomed), offer advanced options for support for LV assistance when respiratory support is not required. In more severe cases of CS, additional support may be necessary, including veno-arterial extracorporeal membrane oxygenation (VA-ECMO) or TandemHeart, which can provide additional respiratory support, which is particularly advantageous in patients with severe pulmonary oedema. However, in patients with significantly reduced ejection fraction, VA-ECMO can increase wall stress and oxygen demand. To address this, the combined use of VA-ECMO and Impella (ECMELLA) offers a synergistic approach, reducing LV filling pressures while simultaneously improving cardiac output.[10,23] When patients continue to experience refractory symptoms of HF or develop shock despite treatment, valve intervention is considered.[24]

Papillary muscle rupture is a rare condition and is associated with a dramatically higher in-hospital mortality rate compared to MI patients without PMR (36.3% vs. 5.3%).[5,25] Complete or partial PMR typically necessitates urgent mitral valve surgery, which is considered the treatment of choice.[7] Still, the overall mortality in this condition is high, reaching more than 40%. The timing of surgical intervention is primarily dictated by the patient's haemodynamic status, with the median time to intervention reported to be approximately 7 days.[10] Similarly, in our analysis, the TEER procedure was performed on the median 6 days after the index MI for patients with PMR, which is much shorter than the median time for TEER in secondary MR. The differences in the median time might be related to the urgency of the procedure in severely decompensated PMR patients. Although surgery is the treatment of choice for PMR, many patients are considered inoperable and face poor outcomes.[26]

The IREMMI group previously compared medical therapy, surgical valve replacement or repair, and TEER in acute MI patients with severe secondary MR. We concluded that conservative treatment is associated with higher mortality than patients who underwent intervention (hazard ratio 2.14, CI 1.51–3.02, $p < 0.01$) at 1 year. Regarding the comparison between the two interventions, procedural success was similar for both surgery and TEER. However, TEER showed a significant advantage in reducing in-hospital mortality (6% vs. 16%; $p = 0.03$) and 1-year mortality (17% vs. 31%; $p = 0.04$). A sub-analysis of the study for patients in CS revealed no difference in TEER safety, efficacy, and post-procedural adverse events between the CS and non-CS groups, as long as haemodynamic stabilization was achieved before the procedure.[27]

Feasibility of TEER in PMR has been reported in previous case reports and series.[28] In a brief report by Chiew *et al.*,[29] conservative ($n = 7$), TEER ($n = 10$), and surgical ($n = 9$) approaches were contrasted for managing MR due to PMR, predominantly in the setting of acute coronary syndrome. The study observed 1-year mortality rates of 100%, 45%, and 33%, respectively, with one additional death in the TEER and conservative groups between 30 days and 1 year. Our group has also published on the feasibility of TEER and effectiveness in PMR, demonstrating success in almost 90% of cases, improving haemodynamic parameters, and serving as a bridge to recovery or if needed surgery.[12,27,28] Our current analysis showed that patients with PMR had less severe LV dysfunction but a much higher prevalence of CS (91% vs. 51%, $p = 0.001$), higher rates of mechanical circulatory support, and underwent intervention earlier than patients with secondary MR. Patients with secondary MR had better outcomes. It appears that, although both PMR and secondary MR occur after MI, they are distinct and should be considered as separate entities. Nonetheless, TEER, despite its limitations, might be considered for patients with either aetiology who are deemed high risk for surgery.

Transcatheter edge-to-edge repair poses technical challenges in post-MI patients due to factors such as a small left atrium, low septal height, complex anatomy with potentially flailing ruptured segments, the patient's overall clinical condition, and the use of mechanical support. Interestingly, our data suggest similar acute procedural success and number of implants; however, more patients in the PMR group eventually required surgical intervention. These findings suggest that TEER for PMR may serve as a definitive treatment or as a bridge to elective surgery. While TEER has demonstrated positive outcomes in post-MI MR, it is important to recognize that even in cases of unfavourable anatomy, TEER can be utilized as a temporary measure to stabilize decompensated patients before proceeding with a definitive surgical mitral intervention or a transcatheter mitral valve replacement.

All current literature including the current analysis has been based on retrospective data and case series,[12,30,31] validation of these findings awaits prospective randomized trials. The EMCAMI trial (Early Transcatheter Mitral Valve Repair After Myocardial Infarction, NCT06282042) is a prospective, multicentre, randomized study comparing the effectiveness of early TEER treatment for clinically significant secondary MR within 60 days after acute MI to conventional medical therapy. Similarly, the CAPITAL MINOS trial (Transcatheter Mitral Valve Repair for Inotrope Dependent Cardiogenic Shock, NCT05298124) is randomizing participants in CS with at least moderate MR to receive either TEER or medical therapy. Both trials aim to provide more insight into this issue.

Several limitations should be acknowledged. Firstly, this is a study of observational data with uneven group sizes, derived from a multinational retrospective registry spanning an extended period, which could be influenced by unmeasured variables. Second, different generations of TEER devices were used. Devices with independent leaflet grasping might enhance procedural success or quality that was not measured in the present study. Third, it is important to note that severe MR, either secondary or primary, could have been present in some patients prior to their presentation with MI. Fourth, this study lacks detailed data on individual treatments administered during hospitalization by local healthcare providers. Fifth, long-term follow-up, although not the primary focus, was incomplete for the secondary aetiology group, which may introduce bias. Sixth, the current analysis focused on decompensated patients; therefore, findings cannot be generalized to stable, mildly symptomatic patients. In addition, TEER in post-MI patients, especially in PMR cases, is a complex procedure and should therefore be considered only in high-volume, experienced centres or supported by an expert team. Finally, rehospitalization data and longer-term clinical outcomes were not available.

Conclusions

In this multicentre registry, we demonstrated that TEER is a feasible therapy for critically ill patients who are considered unsuitable or at very high risk for operation. Most patients showed haemodynamic and clinical improvement, suggesting that TEER may serve as a salvage treatment or bridge to surgery in this population. However, while TEER is a valid option for both PMR and secondary MR, immediate or shot-term outcomes are notably poorer in patients with PMR.

Supplementary Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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